Measurement-based Energy Management at a Low Energy Campus

I. Business as Usual and Exemplary Energy Management

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Business as Usual Energy Management Challenges

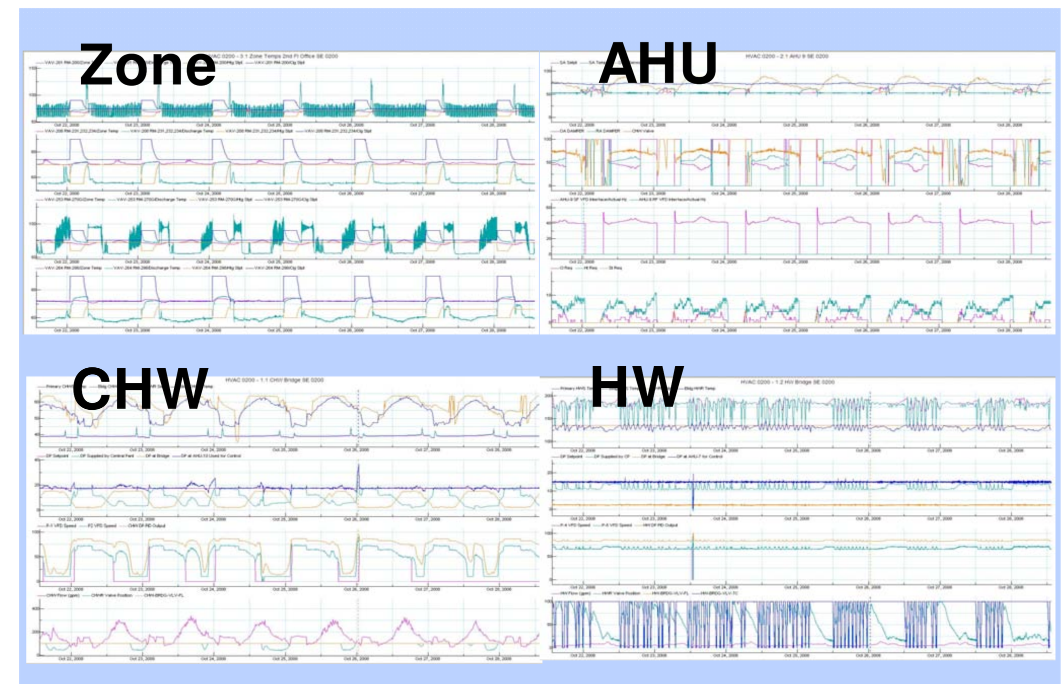
Two critical challenges to processing energy data into actionable information are, first, availability of reliable building energy, and, second, resources to process data into actionable information. In the business as usual case, operations are driven by comfort considerations, utility bills are the primary source of information, and energy performance is not tracked relative to similar buildings. As a result, building performance typically degrades over time as system faults remain unresolved, equipment ages, and controls are not adjusted properly.

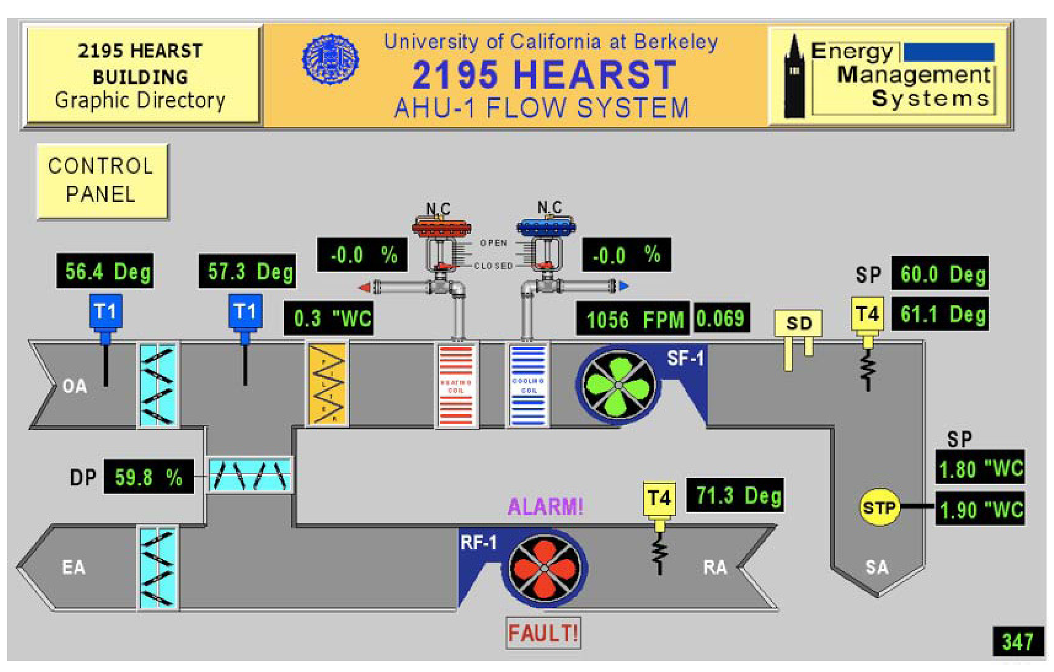
Energy Performance Tracking

- Simple metrics energy/SF EUI, typically annual, sometimes monthly
- Rare to use weather normalized consumption baselines
- At a campus, individual buildings may or may not be metered downstream of the main campus meter

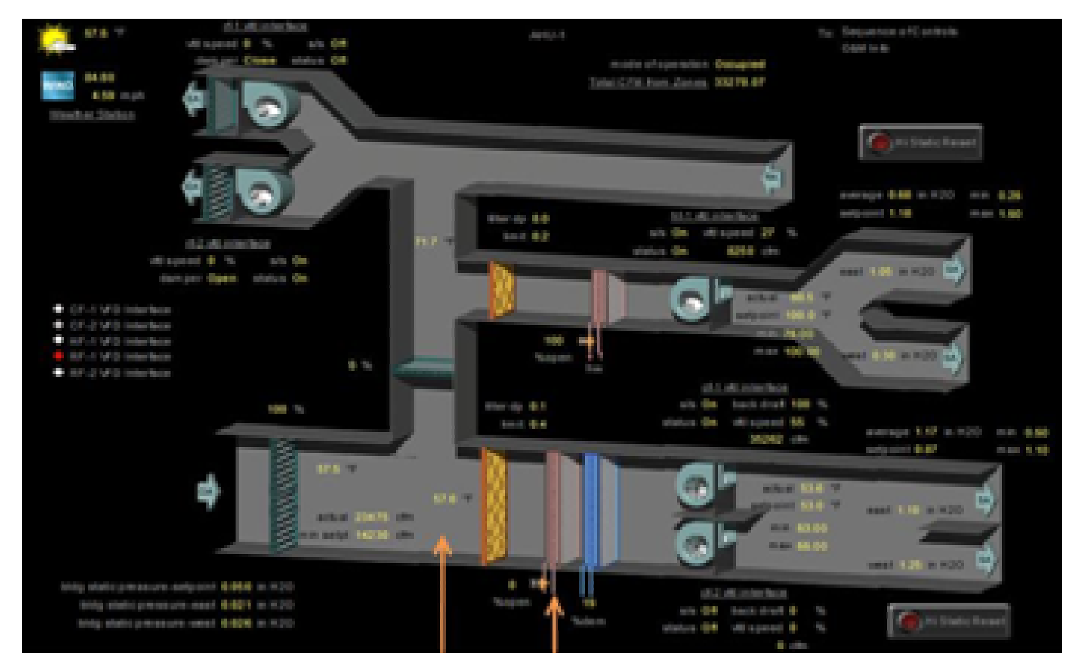
Energy Management Challenges

- Building operations most commonly driven by comfort complaints, not energy
- Data availability – may not have more than utility data for a given building
- Resources – data often must be manually processed to continuously track energy or equipment performance and therefore it is difficult to be proactive
- Performance degrades over time – equipment aging, unresolved faults, etc.





Most campuses have an EMCS that controls building operations and indoor climate. A basic EMCS allows a facility manager to verify equipment settings and temperature set points.



A more advanced EMCS can trend and plot significant volumes of control data and offer remote access. Energy data can be trended but is rarely integrated in daily operations.

UC Merced, a Case of Exemplary Energy Management

In contrast to the business as usual case, UC Merced is an information-rich campus with leading-edge energy management practices. All buildings and the central plant are controlled and monitored through a web-accessible EMCS, energy performance is tracked relative to annual benchmarks, and the campus continues on a net-zero trajectory. Even so, challenges remain – resources required to export and manually process EMCS data into energy metrics precludes proactive use of data and continuous energy tracking relative to targets.

21st Century Sustainable Campus

- The newest campus in the UC system opened in 2005 with a focus on energy and sustainability
- Central Plant thermal energy storage to avoid peak demand

Web-EMCS Data Uses

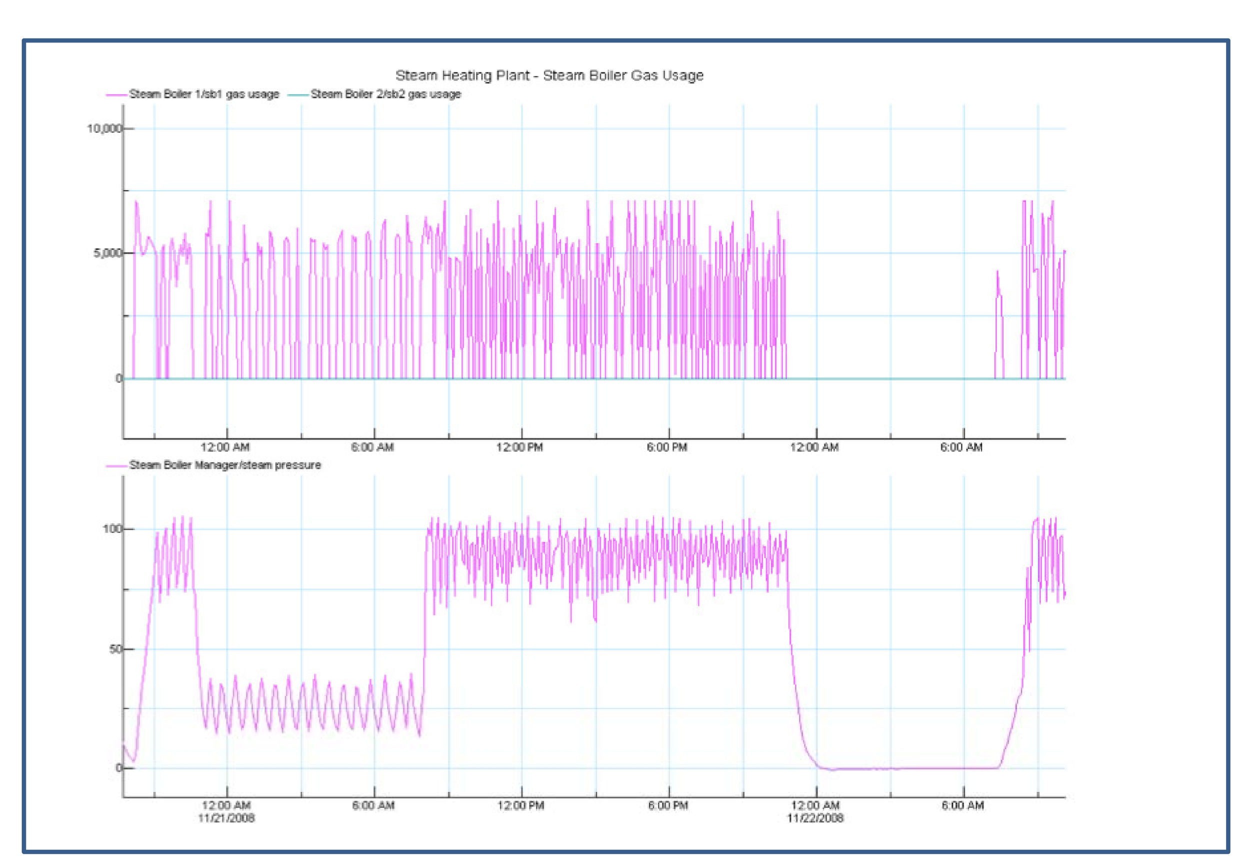
- Automated Logic WebCTRL is an advanced web-EMCS for all buildings and central plant
- 10K pts across 4 main buildings, extensive submetering, energy points included, etc.
- Trends used for trouble shooting and to verify building operations
- Integrating plots into the daily routines of HVAC technicians and central plant operators
- Data are exported for manual calculation of annual energy performance metrics

Energy Benchmarks and Performance Goals

- Custom weather and building-type normalized benchmarks at campus and building level
- Annual energy performance targets are set relative to those benchmarks
- Meter data used monthly for utility recharges

UC Merced Classroom and Office Building

At UC Merced, trend data is exported from the web-EMCS for energy tracking. In the screen shot above, Chilled Water (CHW) supply and return temperature and flow must be converted to tons in order to quantify energy performance. Data gaps and negative values as seen here, must be manually corrected.



Gas usage trends at the central plant (top) showed excessive overnight gas use. Adjusting low overnight steam pressure to zero pressure (bottom) resulted in a 30% reduction in daily gas consumption, and an estimated $2500 in monthly avoided cost.

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II. Prototype EIS: Automated Continuous Performance Tracking

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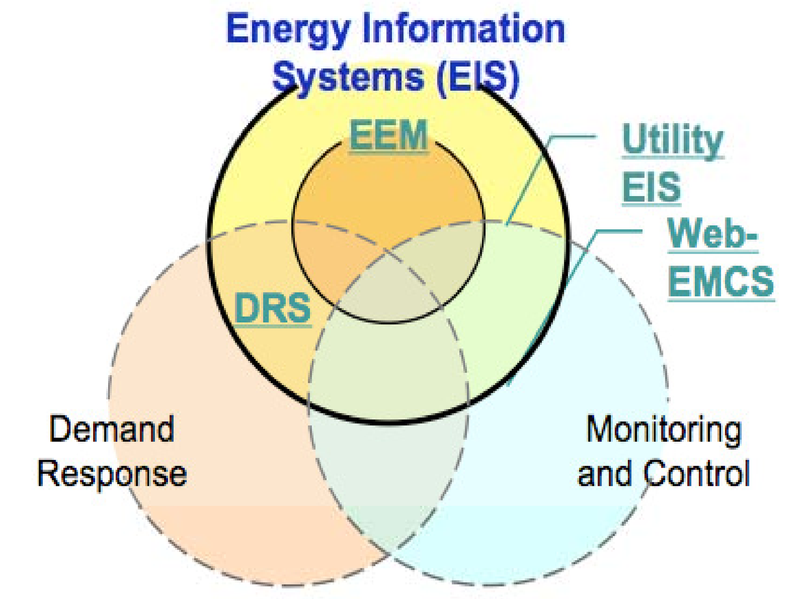
Energy Information Systems (EIS)

EIS are software, data acquisition hardware, and communication systems to collect, analyze and display building energy information. EIS are a promising solution to some of the challenges associated with building energy management as they can process energy data at a more granular time scale than utility bills, make data visible, and through automated analytics provide EIS users with the actionable information needed to optimize building performance on a continuous basis.

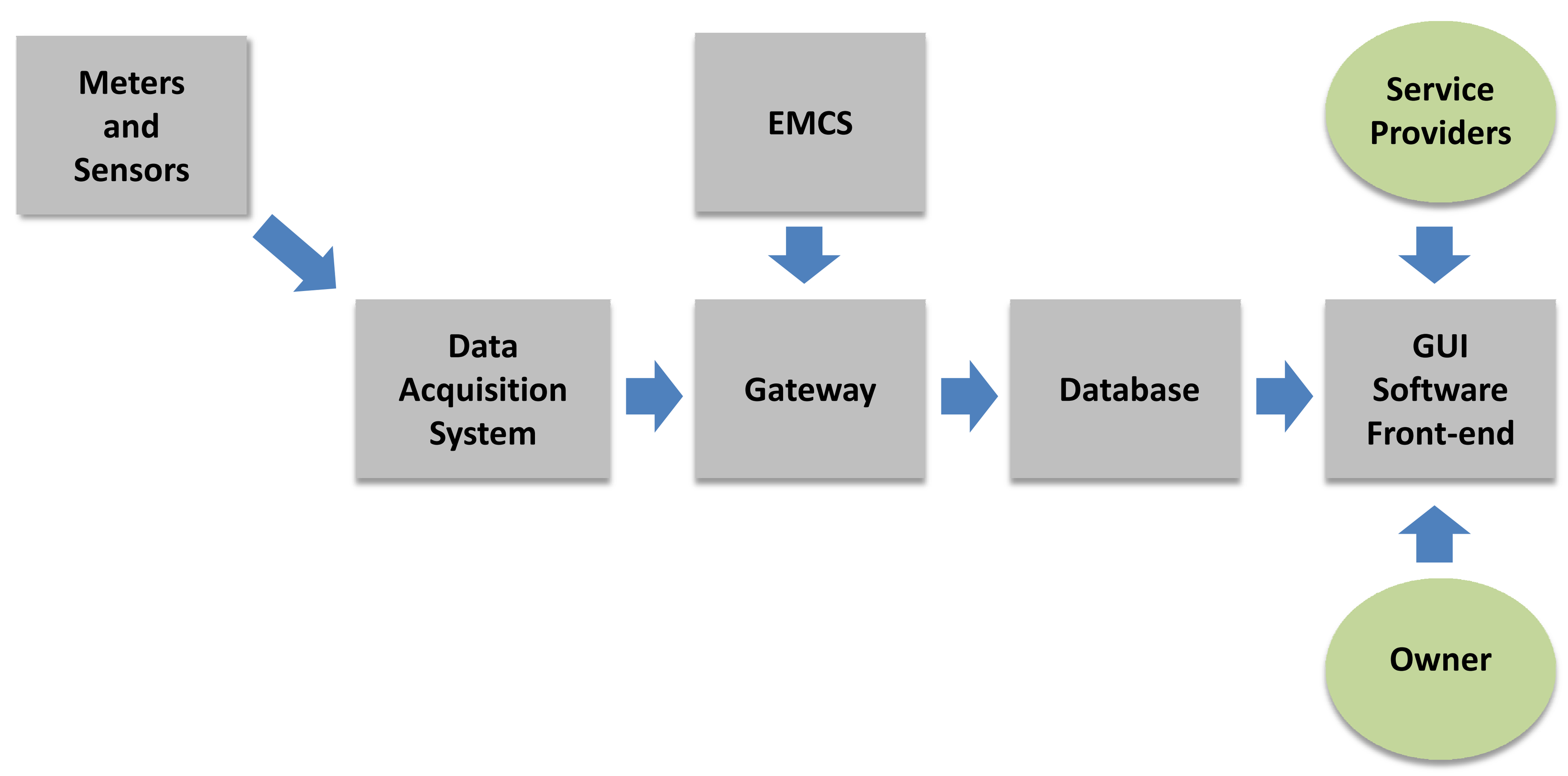
Definition of EIS

- EIS Provide
  - Web-accessible hourly whole building electric data (at a minimum)
  - Graphical/visualization capabilities through GUI front-end
  - Weather, energy price signals, and demand response (DR) information
- EIS combine weather feeds and meter/sensor time series data for analytical capabilities such as
  - Calculation of consumption baselines, forecasts, performance metrics
  - Building or portfolio benchmarking and anomaly detection
  - Load profiling and energy costing
  - Measurement and verification

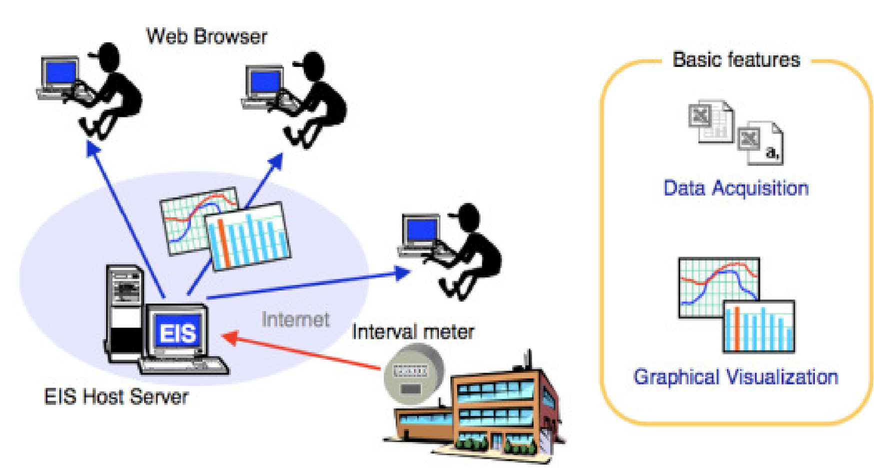


EIS functionality overlaps with enterprise energy management systems, basic utility tools, advanced web-EMCS and demand response systems

EIS Architecture



Hardware, subsystems, and software that comprise typical EIS Architecture. Data for the GUI front-end can be transferred from stand-alone meters and sensors, or from EMCS.



EIS can translate data into actionable information and link the stakeholders that impact building energy use.

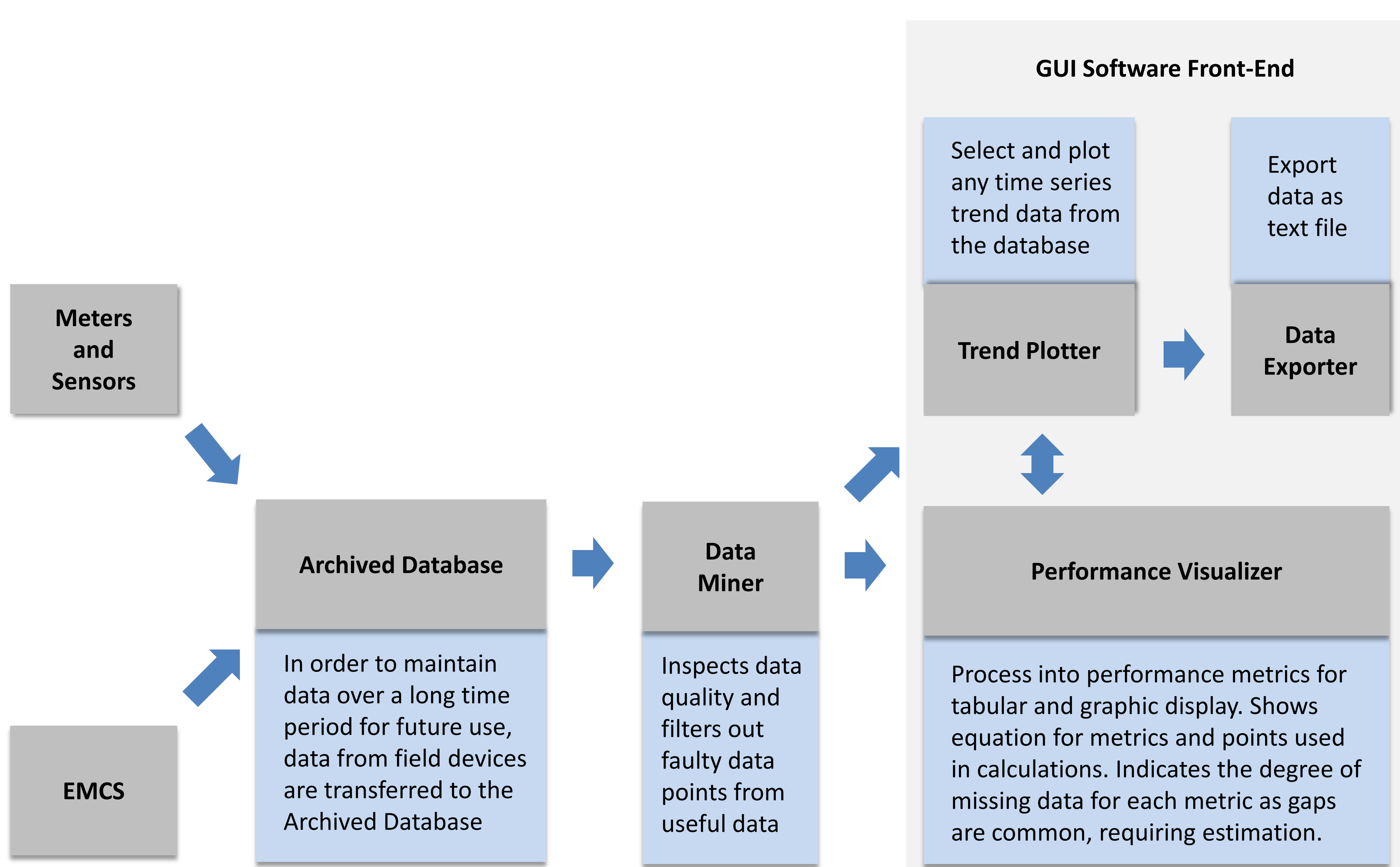
A Prototype EIS for UC Merced

Motivated by UC Merced's challenges in continuous performance tracking and proactive use of EMCS data, a prototype EIS was developed in a joint effort by UC Merced, LBNL, and UTRC in 2009. The prototype EIS allows for visualization and continuous tracking of performance metrics and end uses, such as lighting, as well as increased diagnostic ability. The prototype EIS is currently implemented at the central plant and Classroom and Office Building.

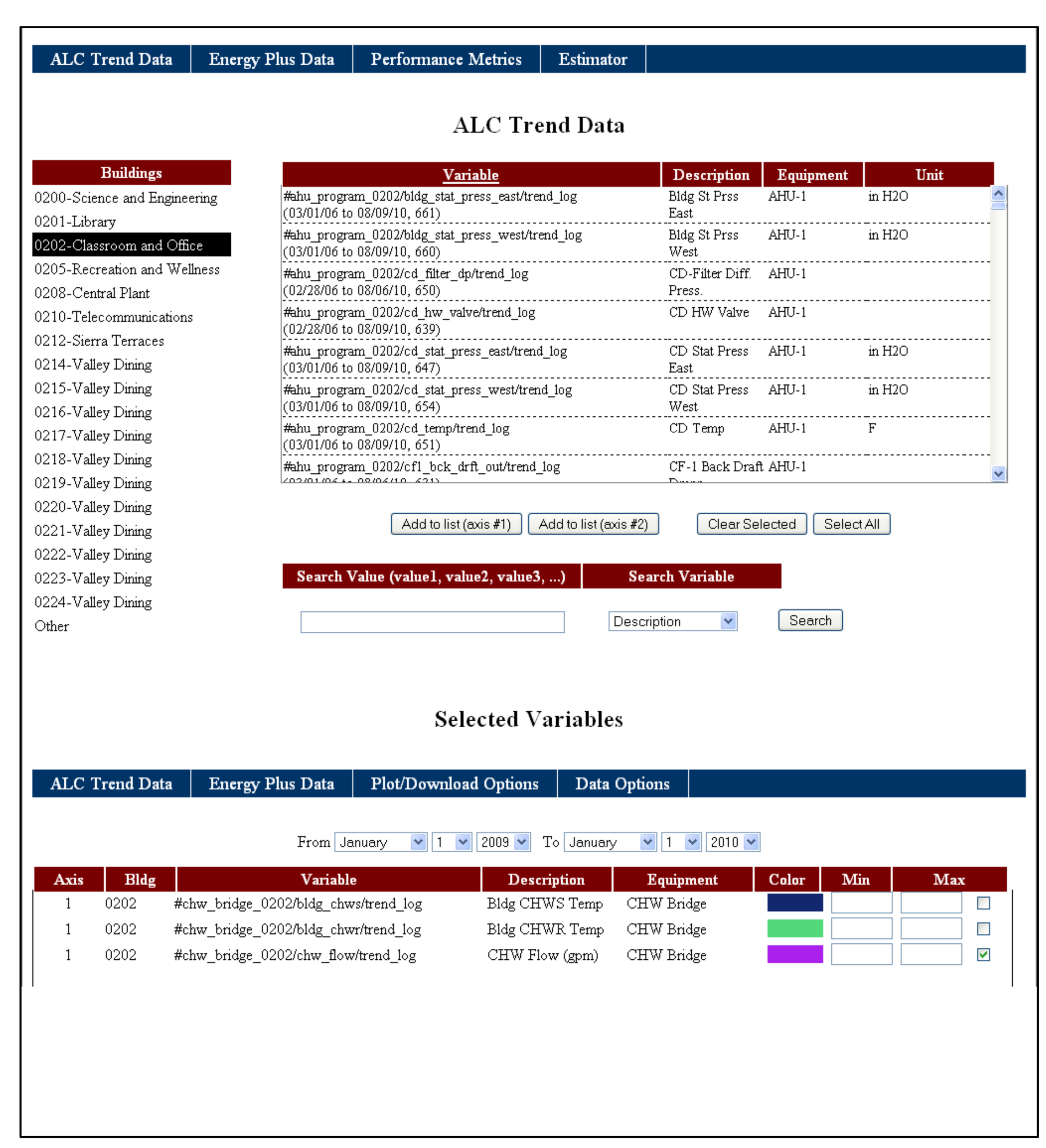
Improvements relative to existing EMCS

- Visual display of energy performance
- Continuous performance tracking: daily, weekly, and monthly energy performance analysis
- Rolling quantification of annual metrics
- End use metrics in relation to benchmarks and indicators of system performance
- Drill down diagnostics: plots of metrics vs. demand indicators

Prototype EIS Components



The prototype EIS follows standard EIS architecture. The GUI consists of the Trend Plotter, Data Exporter, and Performance Visualizer and extends diagnostic capabilities relative to the EMCS.



Screen shot of the Trend Plotter where the user can select archived trends for plotting.

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III. Prototype EIS: Enhanced Metrics and Diagnostics

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Enhanced Performance Metrics and Implementation

Performance metrics consolidate the vast amount of building energy data into a consistent form in order to compare current measured building performance to benchmarks such as comparable buildings. Prior to the prototype EIS, UC Merced's performance metrics weredefined at the whole-building and campus level and expressed relative to benchmarks for UC/CSU campuses with similar climates. Metrics for the prototype EIS have been expanded to include end uses and operational efficiencies.

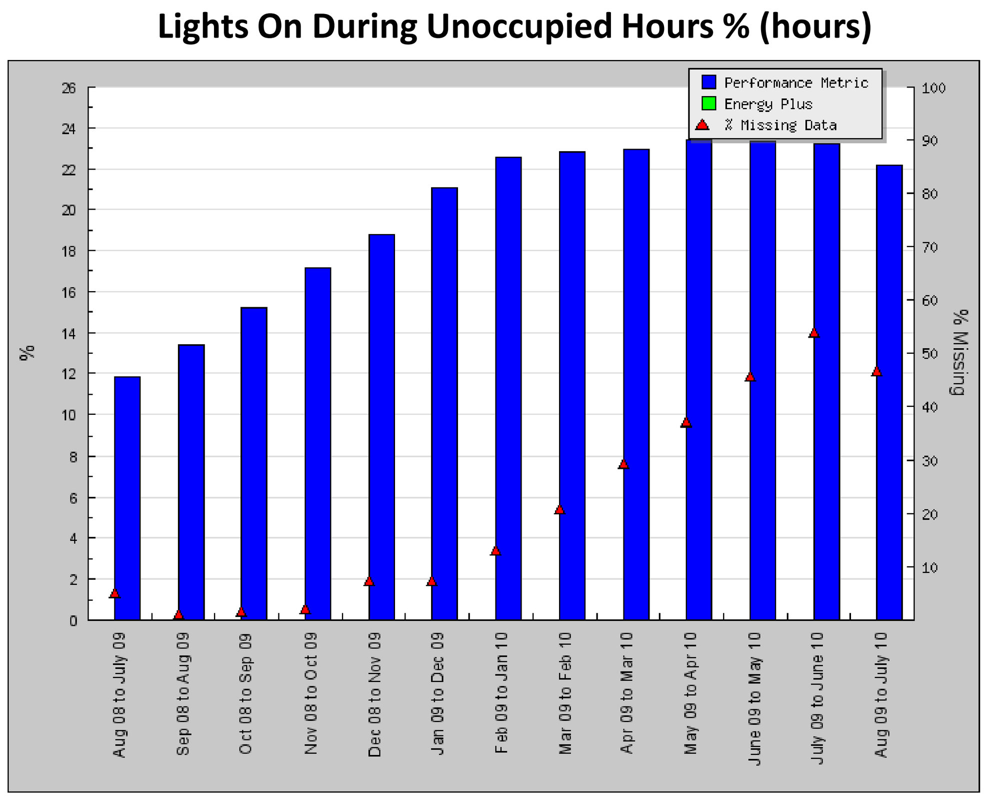
Performance Metrics

- Whole-building and campus chilled water demand, electric demand, gas demand, electric use and gas use
- Currently specific to the Classroom and Office Building but will be adapted to other campus buildings

Implementation of the Prototype EIS

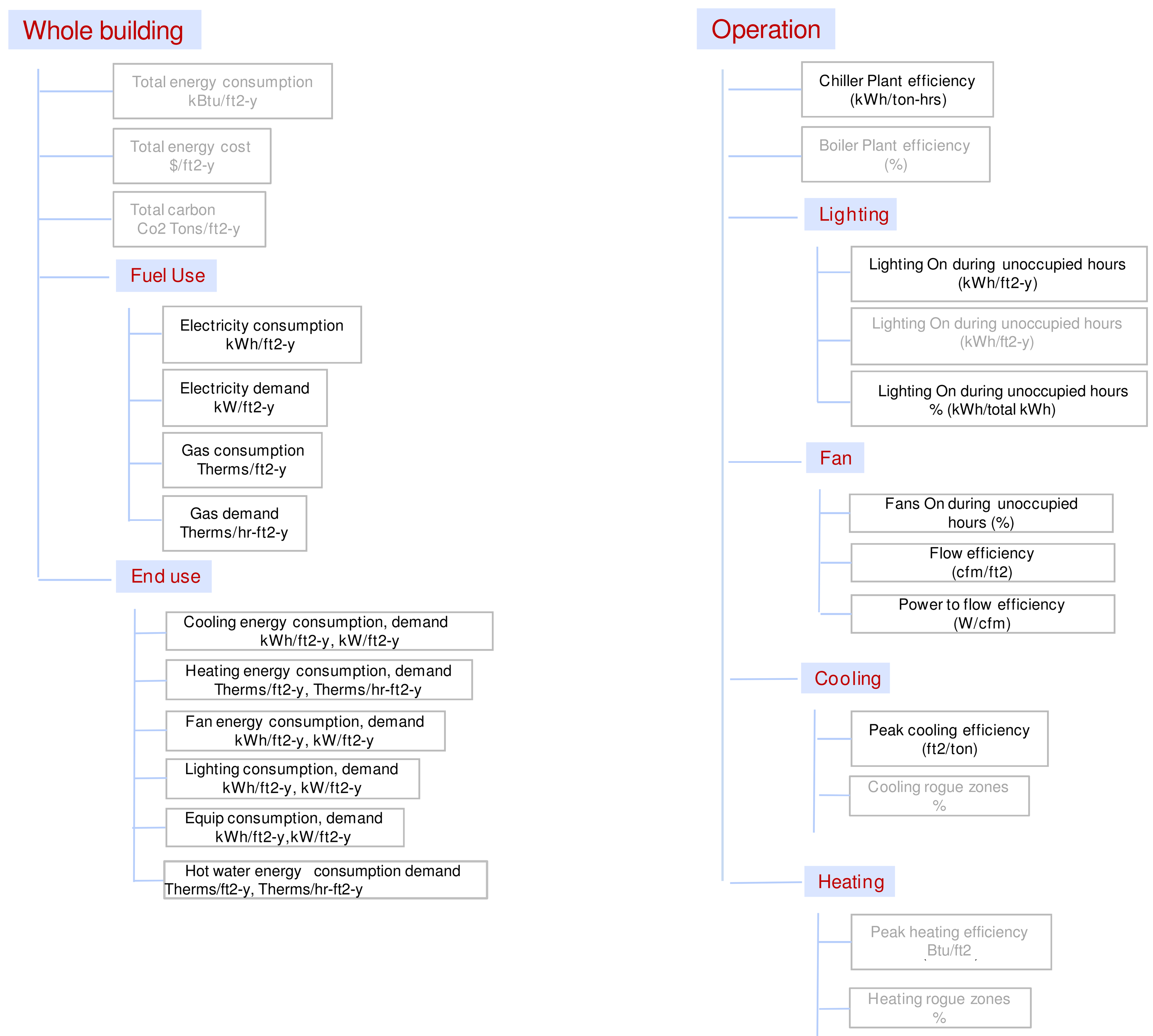
- Trend plotter and data export implemented for all points on campus
- Key energy-related monitoring points that are used for chiller plant include chiller electric demand, campus electric, chilled water and hot water flow and temperature, boiler gas demand

Lights On During Unoccupied Hours % (hours)



Date Range	Value	Unit	Benchmark	Target	Rows
Aug 09 to July 10	22.1844	%			18738

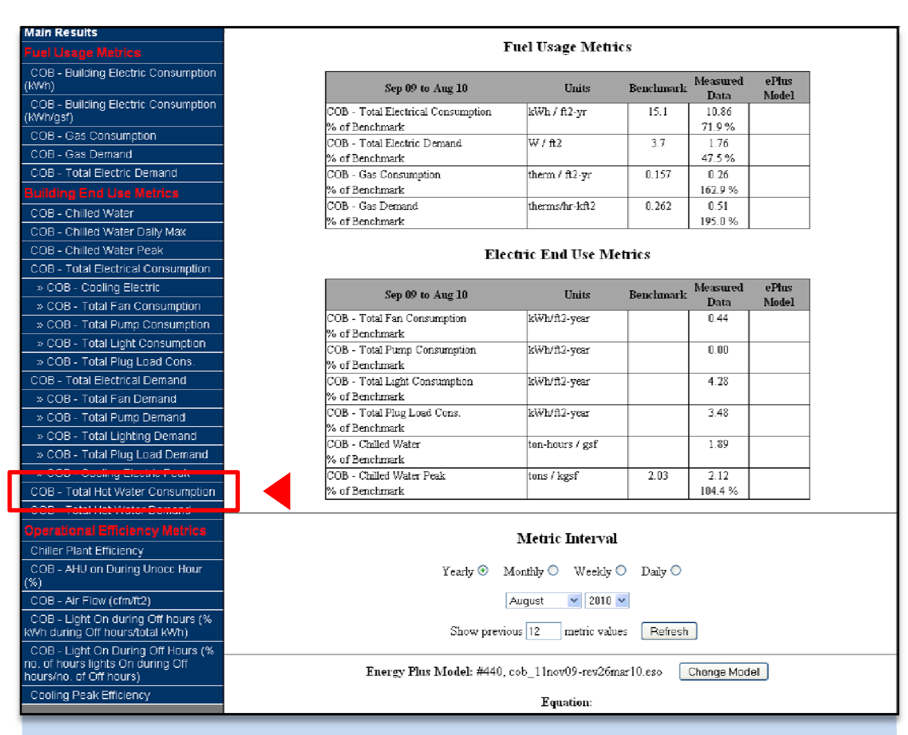
The proportion of lights on during unoccupied hours is a new, operational end-use metric. While no benchmark exists yet, data performance can be tracked over time.



The enhanced set of performance metrics included in the EIS comprise whole building total energy, fuel use, operations, and end-uses. Metrics shown in grey will be added in the future.

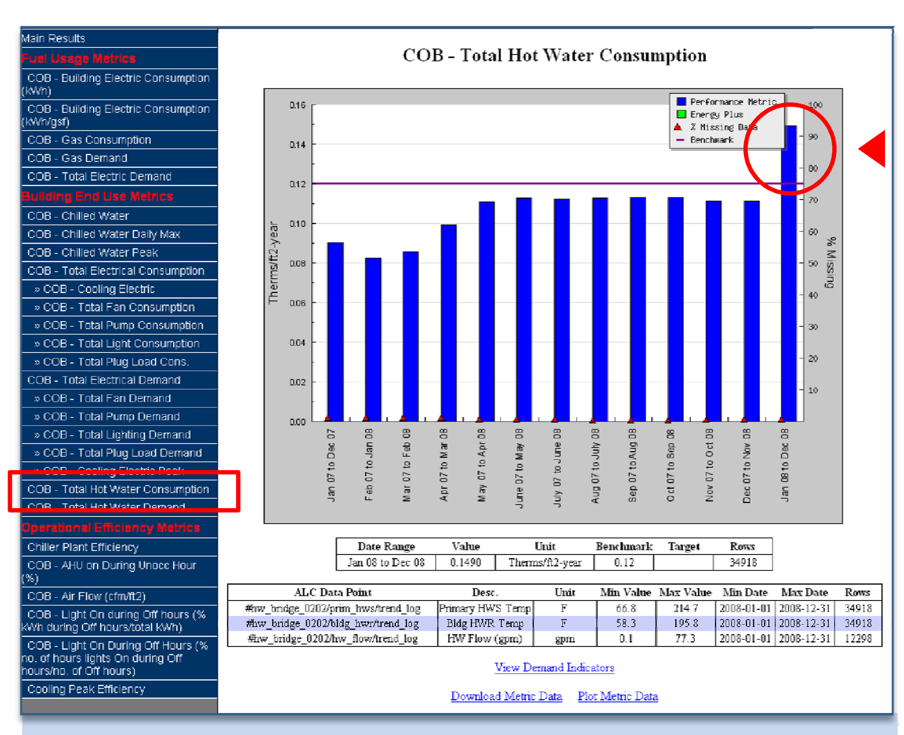
How to Use the Prototype EIS to Identify and Diagnose Energy Waste

The performance metrics provide a framework for identifying system faults and energy waste by comparing data to benchmarks, checking constituent points, and investigating demand indicators, such as heating degree days, that might explain high energy use.



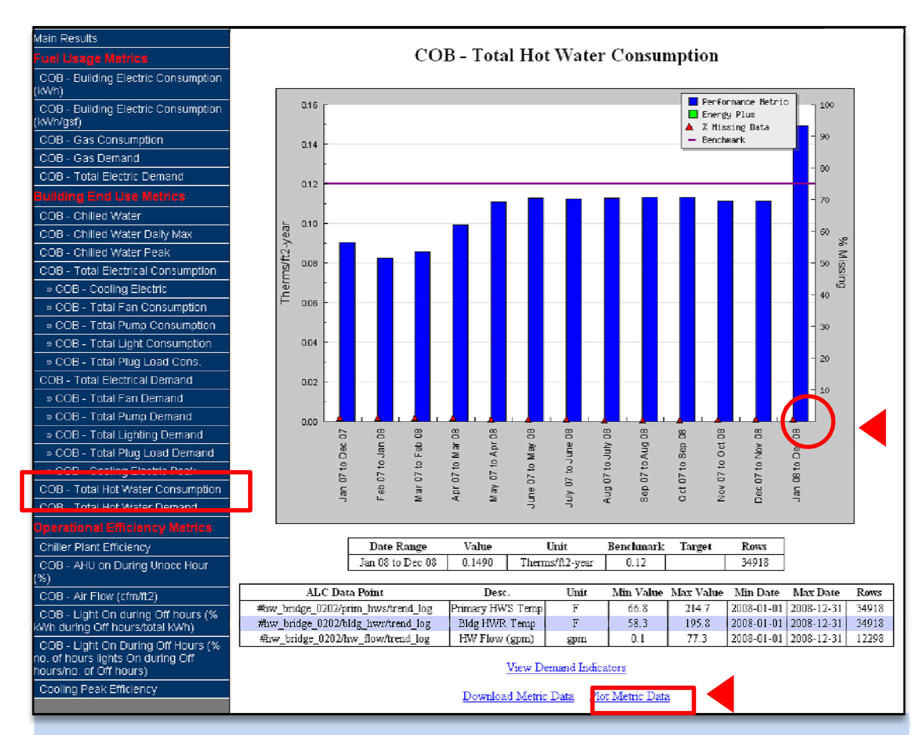
Step 1: View Performance Metrics

At the Performance Metrics home screen, review the summary table. Select each metric for plotting from the blue side bar to check measured data against benchmarks. In this case Total Hot Water Consumption is selected.



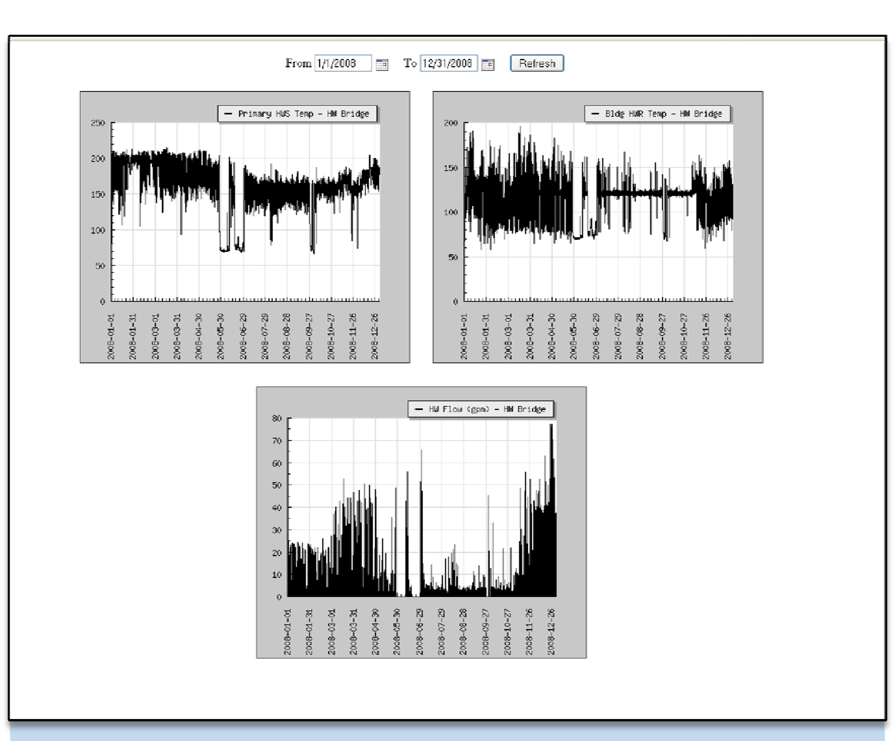
Step 2: Identify Waste

Identify when measured data (blue) has exceeded the benchmark (purple). As seen here, measured data at .16 Therms/ft2-year is higher than the .12 Therms/ft2-year benchmark.



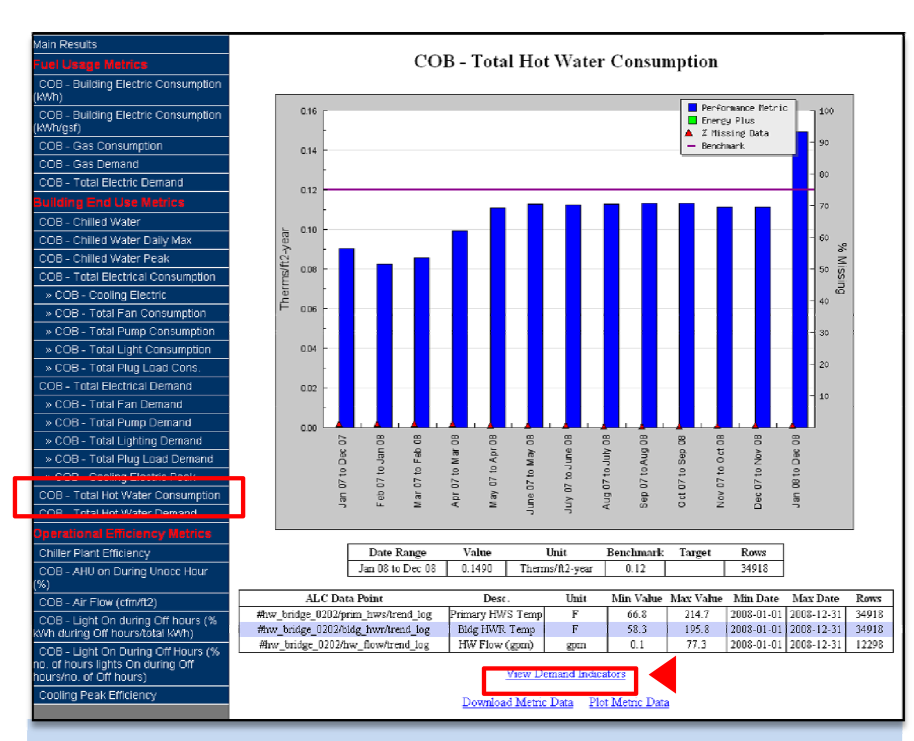
Step 3: Check Data Integrity

Check data integrity by viewing the small red triangles representing % missing data. In this case there is almost no missing data. Go to Plot Data Metric to further investigate constituent points.



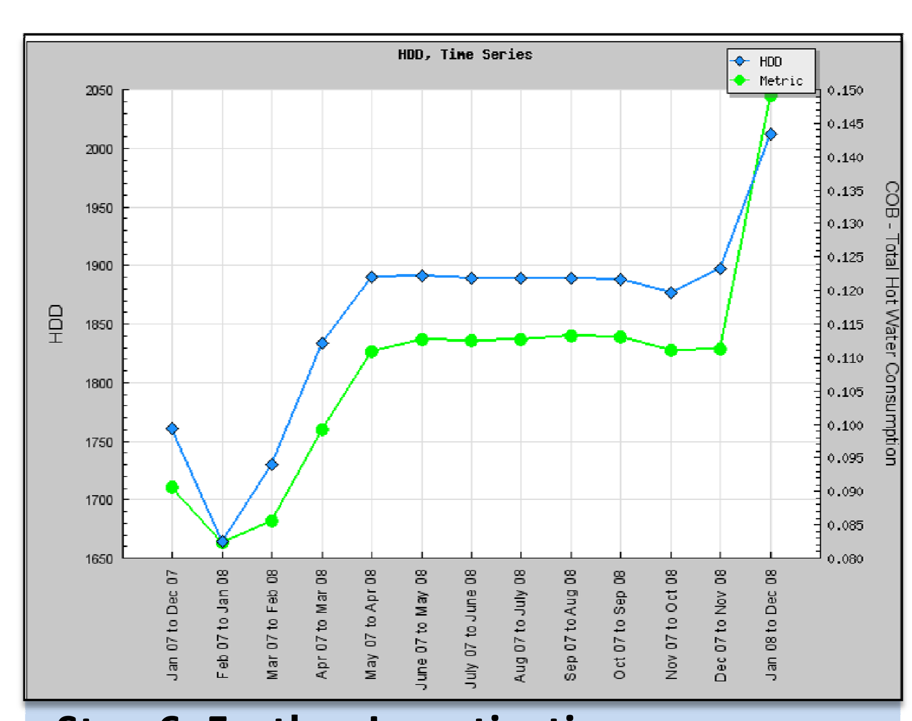
Step 4: View Constituent Points

Check if constituent points are oscillating abnormally as this could point toward a faulty sensor. In this case, points, such as supply and return temperatures and flow, appear normal and sensors and controls are working.



Step 5: Investigate Demand Indicators

Return to the selected metric screen and go to Demand Indicators. Depending on the metric, the user can then compare data to Heating Degree Days (HDD), Cooling Degree Days (CDD), Internal Loads, and Hours of Operation.



Step 6: Further Investigation

In this case, hot water is tracking with HDD, the demand indicator, meaning that weather can not explain the identified waste. As constituent points and demand indicators are normal, the user can conclude there is an operation fault.

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IV. Prototype EIS: Diagnostics in Action and Future Work

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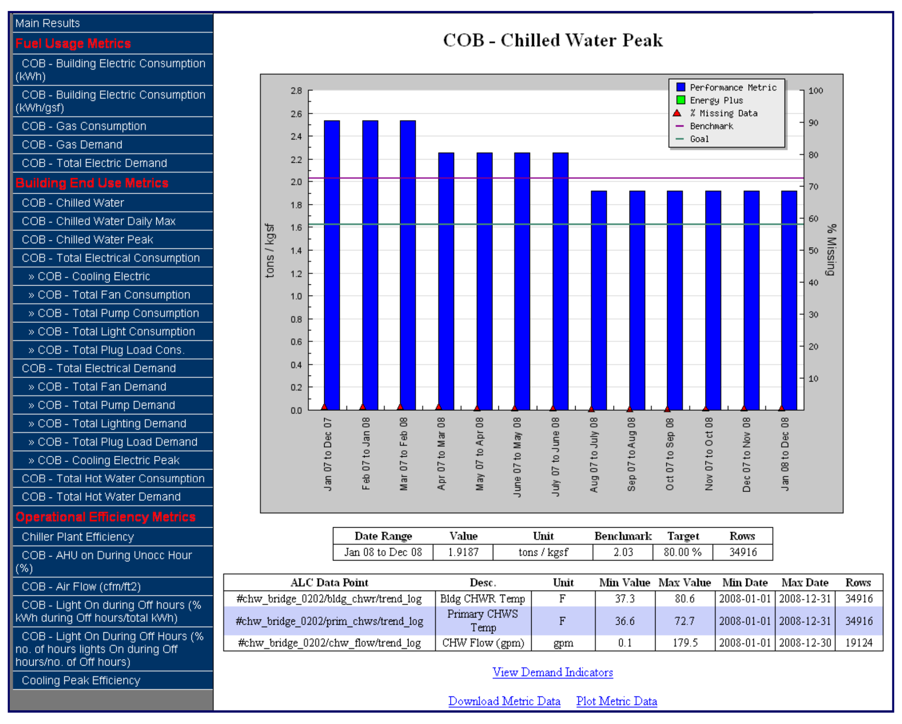
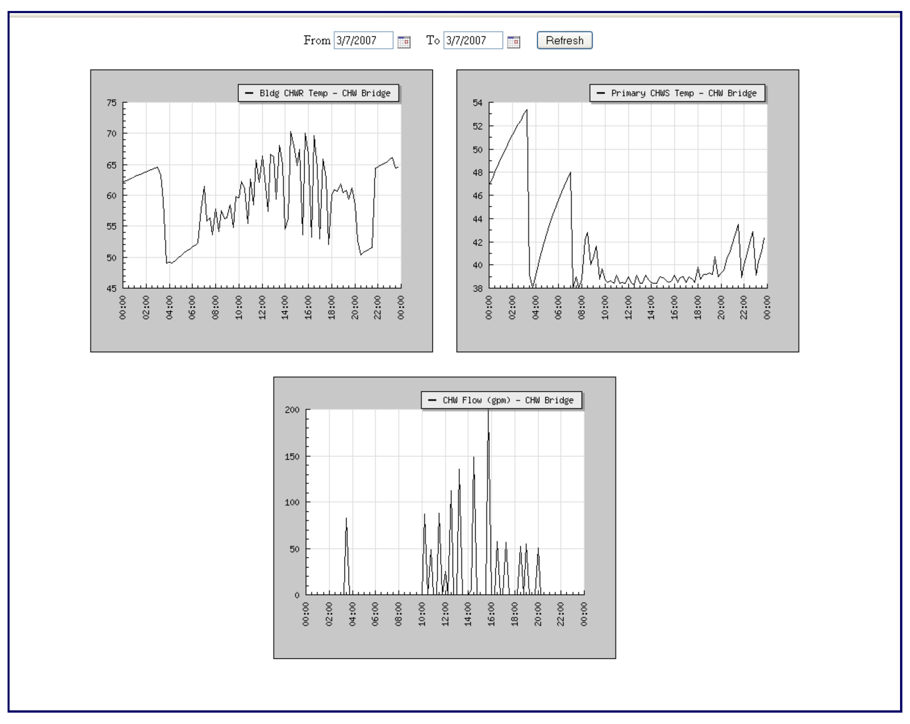
Diagnostics in Action: Peak Chilled Water Demand



Peak Chilled Water Demand
The measured 2.54 tons/kft2 is higher than the benchmark of 2.03 for March 2007. To understand why use exceeds the benchmark, the user should investigate data quality, constituent points, and demand indicators.



Chilled Water Constituent Points
The points for one day in March are fluctuating abnormally from zero to high numbers in a short time interval. The user concludes that there is a faulty sensor or control strategy.

Future Work

Development of the prototype EIS is ongoing toward adapting metrics and components to campus-wide use. The UC Merced energy manager, who has been engaged in every stage of development, is involved in the integration of the tool into all phases of energy management. He expects to use the tool to address a slight upward drift in campus energy use.

Extension to the Science and Engineering Building

- The implementation for COB demonstrated sufficient value to pursue codifying the performance metrics for the campus' most energy intensive building

Integrating EnergyPlus

- The ultimate long-term vision is to have physical models informing operations and fault and detection diagnostics(FDD). Work is ongoing on Model predictive control.
- The prototype EIS has an Energy Plus model that can be run to begin to explore these concepts.
- A more near-term application of the EnergyPlus model may be to compare monthly runs of the model to measured performance metrics as rolling annual metrics may account for last month's weather and input parameters.
- There are limitations to comparing measured performance to similar building types and historic data. The big picture question is does the building meet design intent.

UC Merced Science and Engineering Building

References

Building Energy Information Systems: State of the Technology and User Case Studies
Granderson, J., M.A. Piette, G. Ghatikar, P. Price, LBNL. November 2009. LBNL-2899E.

LBNL EIS project website: http://eis.lbl.gov

Related ACEEE Summer Study 2010 Papers

Panel 3, Monday Session 1: Predicting and Implementing for the Future
Hitting the Whole Target: Setting and Achieving Goals for Deep Efficiency Buildings
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Systems Approach to Energy Efficient Building Operation: Case Studies and Learnings from an Energy Efficient University Campus
Satish Narayanan, United Technologies
Panel 3, Monday Session 2: Better Simulation for Actual Performance
Development and Testing of Model Predictive Control for a Campus Chilled Water Plant with Thermal Storage
Brian Coffey, Lawrence Berkeley National Lab
Panel 3, Wednesday Session 1: Commercial Building Operations
Comparison of Demand Response Performance with an EnergyPlus Model in a Very Low Energy Campus Building
Junqiao Dudley, Lawrence Berkeley National Lab.
Panel 11, Wednesday Session 2: University and Campus Energy Planning
University and Campus Energy Planning
Not Too Fast, Not Too Slow: A Sustainable University Campus Community Sets an Achievable Trajectory Toward Zero Net Energy
John Elliott, UC Merced

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